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Modelling the Ignition of Explosives by Pinch

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To ensure the safe storage and deployment of high explosives one must understand the mechanisms that cause ignition and reaction growth in response to accidental impacts, of which pinch is one. Shear, friction and confinement affect the response. AWE deploys low speed impact tests to understand the physics. In a supporting modelling effort, the High Explosive Response to MEchanical Stimulus (HERMES) material model [1], developed by LLNL and AWE, has been integrated in the Lagrangian finite element hydrocode LS-Dyna and in the Arbitrary Lagrangian Eulerian (ALE) code ALE3D. It has been applied to investigate pinch.

HERMES includes a strength model, a model for porosity generated via damage, and calculates the growth of an ignition parameter derived from the stresses and plastic strain rate. Following ignition HERMES determines the rate of reaction depending on the current reaction extent, the specific surface area, and the pressure. If shocks develop, an entropy-based reaction ensues.

Pinch is modelled by LS-Dyna Lagrangian finite element simulations of an idealised schematic drop test (Fig. 1). A steel drop-hammer, with a flat bottom face, is dropped onto the flat upper end of the cylindrical explosive samples, which stand on a solid steel anvil. The configuration is simpler to model than *e.g.* the Steven Test [1, 2]. Two sample explosives are considered: PETN of density 1.4 g/cc and an HMX-based explosive. This density of PETN was chosen because of the known sensitivity at this density. Drawing on experiments at the Cavendish Laboratory [3], the sample is made tiny compared with the drop hammer and anvil. It is very finely meshed, which requires quite fine adjacent meshes in the hammer and anvil. A coefficient of friction of 0.4 is applied between the explosive and surrounding material. The growth of the ignition parameter and the reaction progress are predicted.

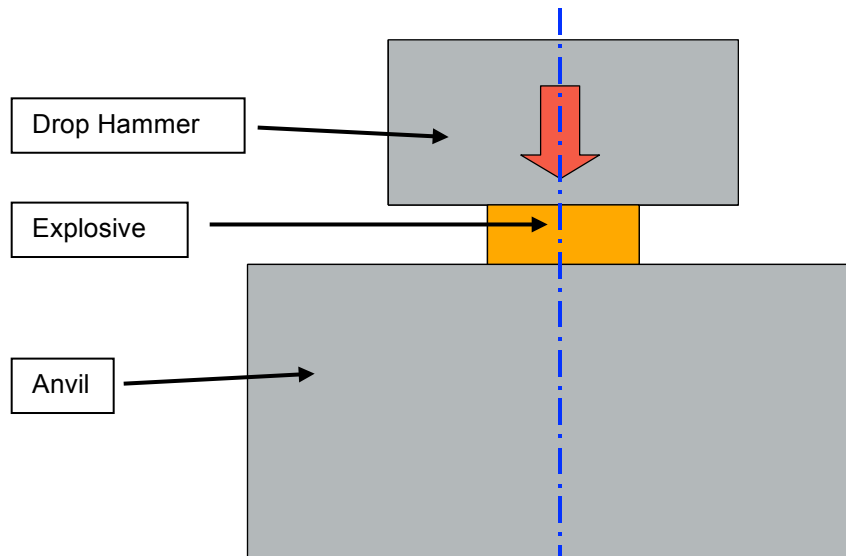


Fig. 1: Schematic of Drop Test

For the PETN an impact speed as low as 1 m / s causes violent reaction across most of the explosive before mesh distortion halts the run. Fig. 2(a) shows the ignition parameter contours at a time of 120 μ s in the sample. There is marked similarity with [1] in that the highest ignition parameter values are associated with shear resulting from friction as the explosive is crushed and flows radially. Just 3 μ s later the map of the extent of reaction, shown in Fig. 2(b), reveals two separate main areas of fully reacted material. The most violent reaction occurs away from the axis of symmetry as in [1] and [3]. For HMX-Based explosive, even up to 10 m/s impacts, the response is much less violent than for PETN, reflecting the known relative sensitivities of these explosives.

Modelling pinch has been shown to be feasible and to offer insights into explosive pinch. Friction and shear greatly affect the response. Future work will explore the use of ALE3D, meshing refinements, parametric studies, and 3D modelling, including asymmetric parameter variations.

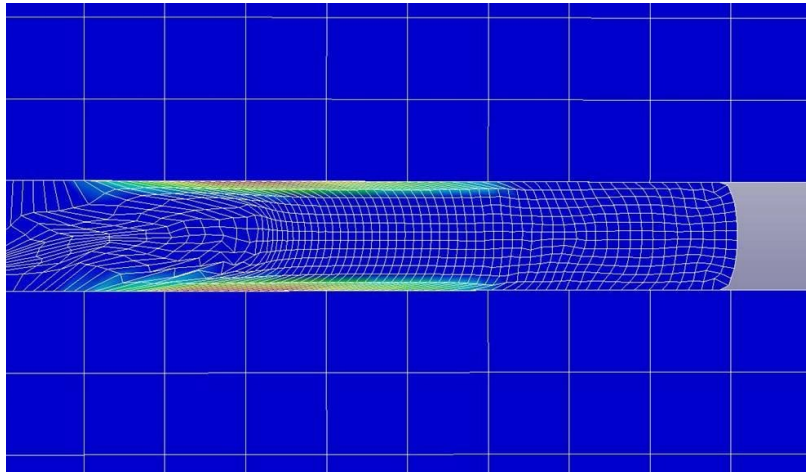
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- [2] Gruau, Picart, Belmas, Bouton, Delmaire-Sizes, Sabatier and Trumel, Ignition of a confined high explosive under low velocity impact, Int. J. Impact Engng., 36, 537-550 (2009)
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a)



b)

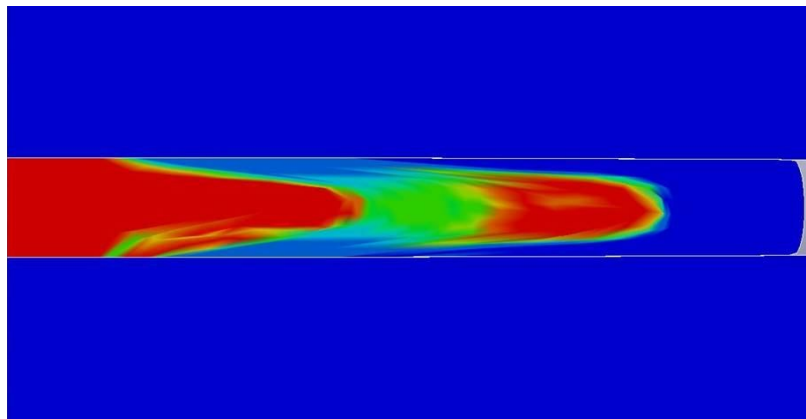


Fig. 2:

- a) Contours of ignition parameter showing deformed mesh at 120 μs with range of ignition parameter 0 (blue) – 352 (red)
- b) Contours of reaction extent at 123 μs . The axis of symmetry is at the left in each case. blue is 0 (no reaction) and red is 1 (fully reacted)